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(54) Radiation shielding

(57) Shields for equipment in which ionising radiation is associated with high electrical gradients, for example X-ray tubes and particle accelerators, incorporate a radiation-absorbing metal, as such or as a compound, and are electrically non-conducting and can be placed in the high electrical gradient region of the equipment. Substances disclosed include dispersions of lead, tungsten, uranium or oxides of these in acrylics, polyesters, PVC, ABS, polyamides, etc.

ERRATUM

SPECIFICATION NO 2007480A

Page 3, line 2, *after CLAIMS Start New Paragraph insert*

1. An electrically non-conducting shield for electrical equipment that produces ionising radiation, which shield incorporates a radiation-absorbing metal and is shaped to lie within the region of high electrical gradient in the equipment adjacent to the radiation-producing components thereof.
2. A shield according to claim 1, forming an evacuable enclosure for the radiation producing components.
3. A shield according to claim 1 or 2, formed of a moulded cast or otherwise shaped matrix of an epoxy resin or other plastics material incorporating the radiation absorbing metal in particulate form, as such or as a non-conducting compound.
4. A shield according to any one of claims 1 to 3, in which the radiation-absorbing metal is tin or a metal of higher atomic number.
5. A shield according to any one of claims 1 to 3, in which the radiation-absorbing metal is tungsten or a metal of higher atomic number.
6. A shield according to any one of claims 1 to 3, in which the radiation absorbing metal is lead, as litharge or in other form.
7. A shield substantially as herein described and shown in Figs 1 and 2 or Fig. 3 of the accompanying drawings.
8. Ionising-radiation producing electrical equipment when provided with a radiation shield as claimed in any preceding claim.

New claims or amendments to claims filed on 18 January 1979

Superseded claims 1 to 8

New or amended claims:-

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(56) Documents cited
GB 811819
GB 439904
GB 420438
GB 379801
GB 374722
GB 280636
(58) Field of search
H5R
(71) Applicants
Lintott Engineering Ltd.
Foundry Lane,
Horsham,
Sussex,
RH13 5PY.
(72) Inventor
Derek Aitken
(74) Agents
Phillips & Leigh

(54) **Radiation shielding**

(57) Shields for equipment in which ionising radiation is associated with high electrical gradients, for example X-ray tubes and particle accelerators, incorporate a radiation-absorbing metal, as such or as a compound, and are electrically non-conducting and can be placed in the high electrical gradient region of the equipment. Substances disclosed include dispersions of lead, tungsten, uranium or oxides of these in acrylics, polyesters, PVC, ABS, polyamides, PTFE, epoxy resins, glass or ceramics. The material used may constitute an evacuable enclosure of the equipment or may be an external shield thereof.

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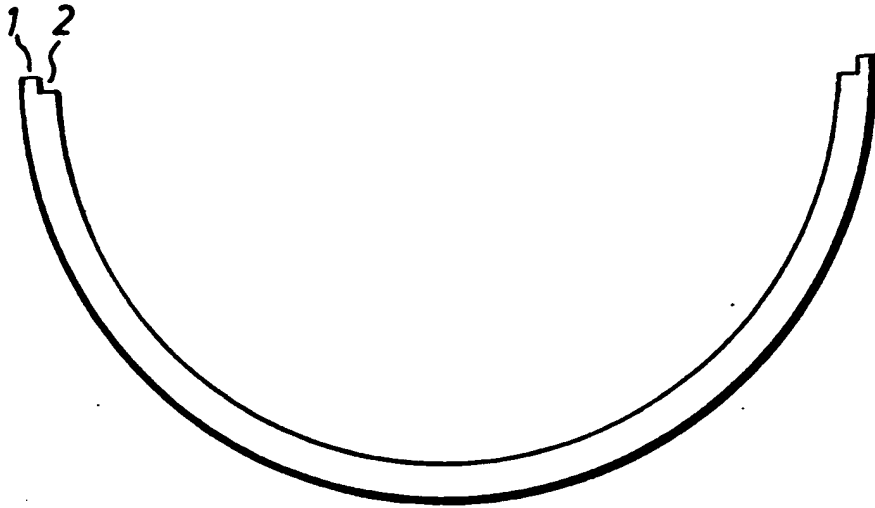


FIG. 1

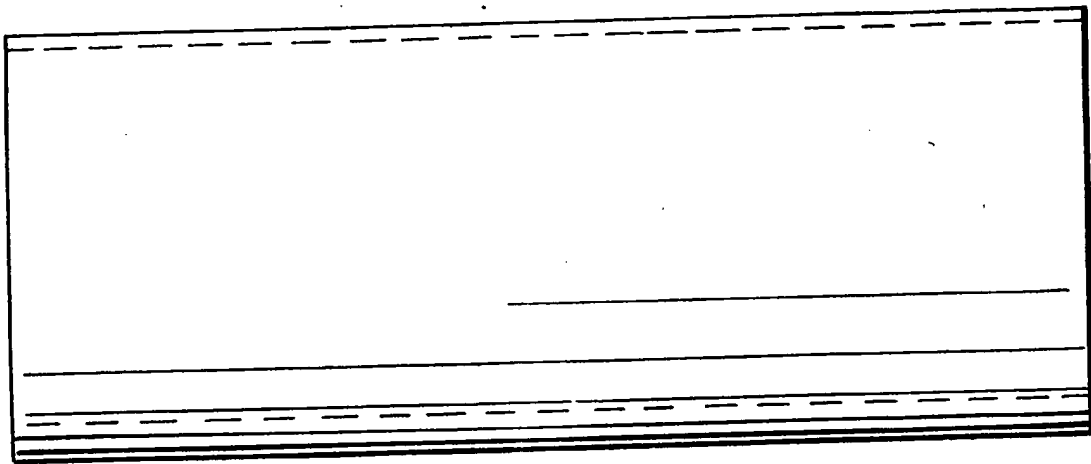


FIG. 2

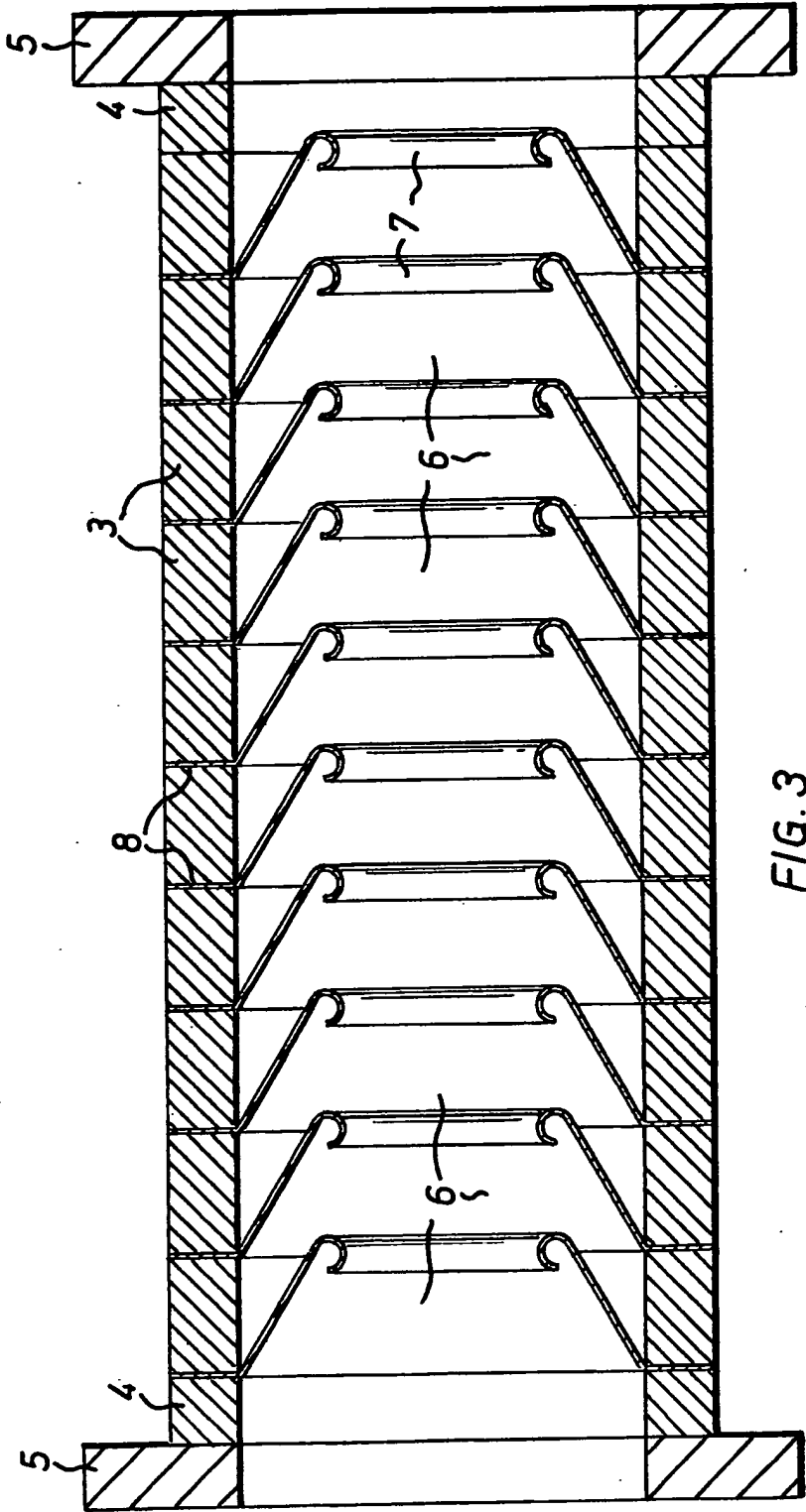


FIG. 3

SPECIFICATION

Radiation shielding

- 5 The invention relates to radiation shields, particularly for equipment in which the production of radiation is associated with high electrical gradients. Commercial ion beam or electron beam equipment, where the accelerator tubes give rise to high radiation levels, is of this kind. 5

Conventional shielding of lead sheeting or concrete, spaced from the radiation source, is often very expensive in the cost of materials or in elaborate fabrication, and may also make equipment excessively bulky or heavy. 10

Our concept is to make shielding that is electrically non-conductive and can therefore be placed in equipment close to the radiation source where the electric field strength is high. Both the bulk of the equipment and the amount of shielding material required can be greatly reduced by this means, without loss of protection.

- 15 The invention accordingly provides an electrically non-conducting shield for electrical equipment that produces ionising radiation, which shield comprises a radiation-absorbing metal and is shaped to lie within the region of high electrical gradient in the equipment adjacent to the radiation-producing components thereof. The metal, even where used in an insulating matrix, is preferably in the form of an electrically non-conducting compound, and the invention extends both to the shields and to equipment incorporating them. 20

Such shields may be made separately and used with equipment in which the radiation producing components are enclosed by other means, such as the conventional glass envelope, or may themselves form an evacuable enclosure.

- Any radiation-absorbing metal may be used, but the absorptive power of metals increases rapidly with atomic number and heavy metals are desirable, preferably of atomic number 50 or more (tin and metals above it) and advantageously of atomic number 74 or more (tungsten and metals above it.) 25

The shielding is conveniently made in moulded or cast form, either by dispersion of the radiation absorbing material in an insulating and bonding plastics matrix such as an epoxy resin, or by ceramics techniques, using for example ceramics or glasses containing lead oxide.

- 30 Alternatively the radiation absorbing material may be a loose or lightly bonded non-conducting fill within a shell of plastics, glass or other material. The exact method of incorporating the radiation absorbing material is unimportant, provided it is present and the shield as a whole is non-conducting. 30

- Where shielding is moulded or cast, the radiation absorbing material content is preferably the maximum within workability limits, well known in themselves in both the plastics and ceramics arts. The state of subdivision of the materials is also largely a matter of convenience in moulding or casting operations. 35

- Lead is the most convenient radiation absorbing metal on grounds of cost and effectiveness, and lead monoxide (litharge) is a particularly suitable form in which to use it, in view of high density and ready availability in convenient form, as sold for paint pigment. Alternatives are however tungsten, particularly in oxide form, or, where maximum absorptive power in minimum volume is required, uranium, conveniently as depleted uranium oxide. 40

- When a plastics matrix is used, selection may be made from many plastics of suitable electrical properties, as determined by the specific application and well known in themselves in electrical equipment. Acrylics, polyesters, polyvinyl chloride, ABS (acrylonitrile-butadiene-styrene), polyamides and polytetrafluoroethylene are all suitable, shaped by sintering, injection moulding, extruding or other suitable means, but we prefer the well known epoxy resins used in electrical equipment for insulating purposes. 45

The accompanying drawings are given as specific examples of components, and in them:

Figures 1 and 2 show one half of an X-ray tube shield in end and side view respectively;

Figure 3 shows an accelerator tube in longitudinal section.

- 50 The X-ray tube shield is 19.9 inches (50.5 cm) long by 15.4 inches (39.2 cm) diameter and 0.625 inches (1.59 cm) thick, and is made in moulds lined with a sheet of melamine resin for each shield, to give a good exterior finish. The moulded shield is machined along the mating flanges 1 and 2 for the counterpart half-shield to give a perfect fit. 50

The mix used is the following:

- 55 45 parts by weight finely divided lead monoxide (litharge) paint pigment 55
6.75 parts by weight resin
2 parts amine hardener

The resin is a Bisphenol-A based material and the hardener is a polyamine, the properties being the following:

- 60 1. PROPERTIES OF THE RESIN: 60

Designation	DOBECKOT-605 (Dr. Beck & Co.) (Trade Mark)
Type of material	Solvent free modified epoxy resin

	Appearance	Clear light straw liquid	
	Viscosity at 20°C	1,000 cps.	
	Flash point	>100°C.	
5	Epoxy equivalent	200 ± 20	5
	Specific Gravity at 20°C	1.11	

2. PROPERTIES OF THE HARDENER:

10	Designation	HARDENER 762 BE2 (Dr. Beck & Co.)	10
	Type of Material	Polyamine	
15	Appearance	Blue liquid	15
	Viscosity at 20°C.	80 cps.	
	Flash point	>100°C.	
	Specific Gravity at 20°C.	0.97	

3. PROPERTIES OF THE RESIN/HARDENER MIX AS SUCH:

	Viscosity at 20°C.	800 cps	
25	Usable Pot life at 20°C	30 minutes	25
	at 30°C.	20 minutes	
	at 40°C.	10 minutes	
	Gel Time at 100°C.	3 minutes	
30	Cure at 120°C.	30 - 60 minutes	30

4. ELECTRICAL PROPERTIES (CURED RESIN AS SUCH):

	Electric Strength	1000 volts/mil	
35	BSS 2782 Part 2 1965 Method 201 C		35
	Volume Resistivity	1×10^{15} ohm cm	
	BSS 2782 Part 2 1965 Method 202 A		
	Surface Resistivity	8×10^{14} ohm cm	
	BSS 2782 Part 2 1965 Method 203 A		
40	Permittivity	2.5	40
	Dielectric Loss Angle (Tan δ)	0.010	
	Shrinkage %	0.5	

Shields as made with the litharge based mix have excellent electrical properties with a volume resistivity better than 10^{12} ohm cm and an electric strength of approx. 30 MV/m. A test sample of the material 1 cm in thickness reduces the intensity of 150 KV X-rays from a commercial tube by a factor of 600, and the shields are thus readily capable of reducing radiation levels below permitted maxima, for example 0.25 mil-lirads/hour in the U.S.A.

Suitable amounts of other metal compounds for making up mixes as above are readily calculated from their density. Amounts which may be used in substitution for the 45 parts of litharge are for example (by weight):

	PbO ₂	-	44.2 parts	
	PbF ₂	-	38.9 parts	
55	UO ₂	-	51.7 parts	55
	UN	-	67.5 parts	
	WO ₂	-	57.1 parts	

An example of a shield which is in fact the vacuum enclosing envelope of the radiation source is shown in Figure 3. It consists of a number of rings 3 of the litharge-based mix given above interposed between the metal electrodes of a graded accelerator tube. The tube is of a design used in commercial ion implanters for silicon chips, and is schematically shown, without electrical connections or details of the end rings 4 and metal end flanges 5 by which the tube is mated into the vacuum system of the implanter. The electrodes 6 are of flanged frusto-conical form with the smaller, inner ends 7 rolled and the flanges 8 reaching the surface of the shield, for electrical connections. They are made of aluminium, or for steeper electrical gradients

titanium.

CLAIMS

1. An electrically non-conducting shield for electrical equipment that produces ionising radiation, which
5 shield incorporates a radiation-absorbing metal and is shaped to lie within the region of high electrical
gradient in the equipment adjacent to and forming an evacuable enclosure for the radiation producing
components. 5
2. A shield according to claim 1, formed of a moulded cast or otherwise shaped matrix of an epoxy resin
or other plastics material incorporating the radiation absorbing metal in particulate form, as such or as a
10 non-conducting compound. 10
3. A shield according to claim 1 or 2, in which the radiation-absorbing metal is tin or a metal of higher
atomic number.
4. A shield according to claim 1 or 2, in which the radiation-absorbing metal is tungsten or a metal of
higher atomic number.
- 15 5. A shield according to claim 1 or 2, in which the radiation absorbing metal is lead, as litharge or in other 15
form.
6. A shield substantially as herein described and shown in Figures 1 and 2 or Figure 3 of the accompany-
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7. Ionising-radiation producing electrical equipment when provided with a radiation shield as claimed in
20 any preceding claim. 20